Measuring Mid- and Near-Field Rotational Ground Motions in Taiwan

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Abstract

Large rotational motions (~200 micro-radians) excited by the 1999 Chi-Chi (Mw=7.6), Taiwan, earthquake were inferred from a dense accelerometer array 6 km from the northern end of the fault where large surface slips were observed (Huang, 2003). In December, 2000, C. C. Liu and B. S. Huang began measuring rotation motions using a PVC-5 transducer (0.2V/rad/sec) and a GyroChip sensor (1.43 V/rad/sec) at station HRLT near Hualien. However, no significant rotation motions were observed in the 5 years since, probably due to the low sensor sensitivity although many earthquakes occurred nearby. In July, 2004, Liu and Huang began measuring rotation motions using a far more sensitive triaxial sensor, R-1, made by eentec/PMD (50 V/rad/sec) at station HGSD near Cheng-Kung.

At 18:50, September 26, 2005, an Mw=4.7 earthquake occurred 29 km south of station HGSD. The observed maximum rotation velocity for the EW, NS and Z component is 306, 499, and 1863 micro-rad/s, respectively. At 17:01, January 8, 2006, an Mw=4.6 earthquake occurred 36 km south of station HGSD. The observed maximum rotation velocity for the EW, NS and Z component is 98, 183, and 217 micro-rad/s, respectively. In both cases, the observed rotation waveforms (prominent frequency ~3 Hz) are far above the background noise (signal-to-noise ratio is usually >100), and imply rotational motions of a few tens of micro-radians. However, the R-1 sensor has not been rigorously calibrated, and Liu and Huang are not sure of these measurements, which are orders of magnitude larger than a simple theoretical model by Bouchon and Aki (1982) would predict for these small earthquakes.

To further investigate the question whether rotational ground motions are significant or not in the mid- and near-field of earthquakes, we are now planning a more careful experiment at two sites in Taiwan. Two R-1 and two RSB-20 (made by PMD) rotational velocity sensors are now being tested and calibrated by Robert Nigbor of UCLA and others before installation in Taiwan in 2007. At each site, a 32-channel 24-bit datalogger will be used to record continuously the R-1 and RSB-20 sensors, as well as 8 three-component linear accelerometers deployed adjacently (with spacing of ~100 meters).

Ground Rotational Motions of the 1999 Chi-Chi, Taiwan Earthquake Inferred from Dense Strong Motion Array Observations (Near-Field)

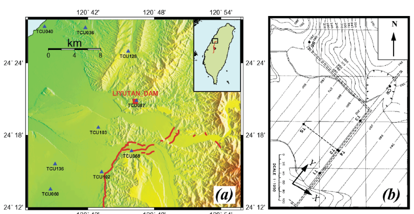


Figure 1. (a) Station distribution map of the CWB strong motion network (solid triangles), the Li-Yu-Tan seismic array (solid square) and surface rupture traces (thick lines) of the Chi-Chi earthquake. (b) Li-Yu-Tan array configuration and reference system. Arrows marked X and Y indicate the directions of ground motion axes employed in this study.

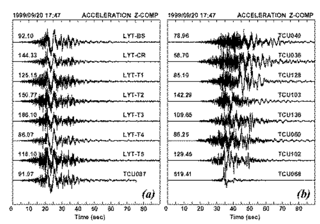


Figure 2. (a) Vertical acceleration seismograms of the Li-Yu-Tan array and the CWB strong motion station (TCU087). Station TCU087 is located about several hundred meters away from this dense array. (b) Vertical acceleration seismograms of the CWB strong motion stations around the northern end of the Chi-Chi earthquake fault (See Figure 1a). Station TCU068 is located on the hanging wall side of the rupture trace, and others are located on the footwall side.

Rotation motions (Wz, Wx, Wy) were computed from the translational velocities (***Ux, Uy, Uz***) as follows:

Wz=1/2(Uy/x-Ux/y), Wx=(Uz/y), Wy=(Uz/x)

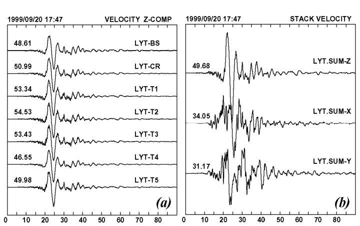


Figure 3. (a) Vertical ground velocity seismograms (in cm/sec) integrated from acceleration traces as shown in Figure 1a. (b) Stacked array seismograms of ground velocities of the Li-Yu-Tan site.

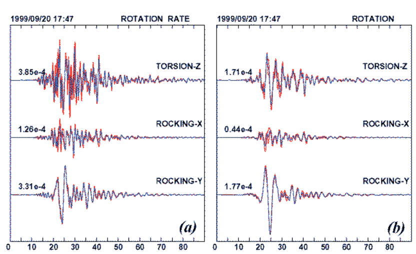


Figure 4. (a) Estimated three-component ground rotation rates. (b) Rotations from the Li-Yu-Tan seismic array for the 1999 Chi-Chi, Taiwan earthquake. Blue lines denote mean values, and red lines show one standard deviation band.

Two Earthquakes Recorded by both Broadband and Rotation Sensors

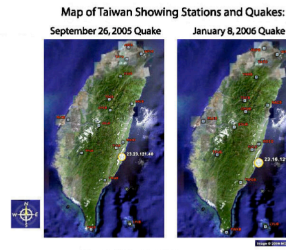


Figure 5

The September 26, 2005, earthquake

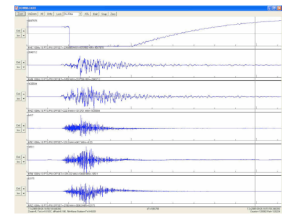


Figure 6

The January 8, 2006, earthquake

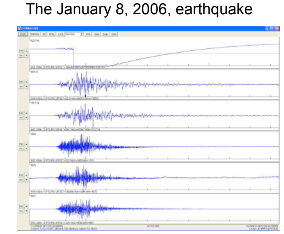


Figure 7

Figure 5. Map of Taiwan showing the location of the HGSD station, the epicenter of the September 26, 2005 earthquake, and the epicenter of the January 8, 2006, earthquake.

Figure 6 and 7. Recorded data for the September 26, 2005, earthquake and the January 8, 2006, earthquake. The top three traces are from the three-component broadband velocity seismometer, and the bottom three traces are from the triaxial rotational transducer. Each time tick is 10 seconds.

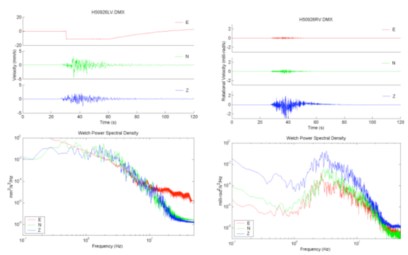


Figure 8. Re-plotting the observed data for the September 26, 2005 earthquake on the same y-axis scale for the two on-scale broadband velocity signals (second and third frames of left panel) and their corresponding power spectral densities are shown in the bottom frame. Since the E-component is clipped, its power spectral density should be ignored. Right panel are the sample plotting for the rotational velocity signals.

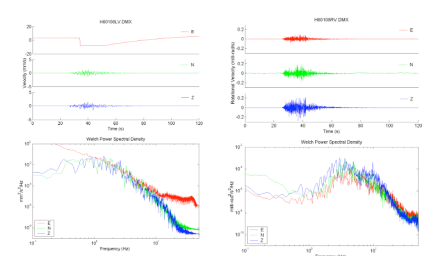
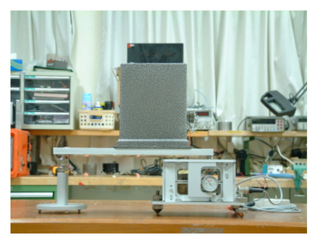
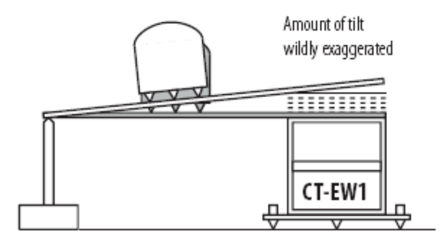


Figure 9. Re-plotting the observed data for the January 8, 2006, earthquake on the same y-axis scale for the two on-scale broadband velocity signals (second and third frames of left panel) and their corresponding power spectral densities are shown in the bottom frame of left panel. Since the E-component is clipped, its power spectral density should be ignored. Right panel are the sample plotting for the rotational velocity signals.

Calibrate RSB20 with CT-EW1

Absolute calibration of RSB20 rotational broadband seismometer





Restituted Angular Velocity and Restituted Angular Displacement are shown

Future works:

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